Bottom Boundary Layer and Suspended Sediment Dynamics: Model-Data Comparisons

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LONG-TERM GOALS

The long term objective of our research is to understand and predict the dynamics of wave and current bottom boundary layers and suspended sediment over natural seabeds in the shallow water environment.

OBJECTIVES

The objectives of this research project are to expand the capabilities of an existing numerical model of bottom boundary layer physics, sediment transport, and morphologic evolution for application on natural beaches and to evaluate the resulting model with field observations of near bed velocity and concentration. We use the model-data comparisons to help interpret field observations over complex topography and to quantify the strengths and weaknesses in the model's physics.

APPROACH

We have modified an existing 2-dimensional bottom boundary layer model, Dune2D, for application with natural waves and seabed morphology. Prior to this project, the Dune2D model, developed by researchers a the Technical University of Denmark, assumed single frequency horizontally oscillating free stream forcing with a variable current, with a rigid lid upper boundary condition and periodic lower boundary condition. The model employs either a zero-, first-, or second-order closure scheme to resolve the relevant dynamics of wave and current boundary layers over smooth and rough movable sand beds and it includes one of several sediment transport models. We have maintained the stablished physics, but modified the forcing and boundary conditions.

Second-order closure models, such as Dune2D, have favorably been compared with laboratory observations (Fredsoe et al., 1999 and Andersen, 1999), but have not been compared with field observations. The model is being compared with velocity observations obtained during Duck94 (Foster et al, 2000), SandyDuck by collaborators Thornton and Stanton of the Naval Postgraduate School. The model skill will be quantified with time-averaged and time-varying statistics. We will calculate the root-mean-square deviations (RMSD) of the: turbulent kinetic energy, dissipation, and velocity amplitude and phase for each data set. The time-varying statistics will be evaluated with the RMSD between the model generated and observed quantities at each phase of the wave. This

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technique will allow us to identify particular wave amplitudes and phases when the comparisons are favorable and unfavorable.

WORK COMPLETED

Thus far, several technical objectives have been met. First, we have modified the model to allow for forcing of measured velocity profiles over measured topography. This was accomplished at the Ohio State University and during two visits to the Danish Technical University. Scientific visits to NPS have yielded working data sets for further model evaluation. Second, we have evaluated the model predicted boundary layer velocity, suspended sediment concentration, and bed load concentration with two independent data sets measured during the SandyDuck experiment by Stanton and Thornton of the Naval Postgraduate School.

RESULTS

The model-data comparisons have thus far, identified several interesting phenomena. In the below example the model is compared to acoustic doppler observations made in several meters of water over a rough bed with a definitive 25 cm high bedform.

As expected the model predicted a boundary layer thickness for flow over the measured bedform to be significantly higher than for flow over a flat rough bed. However, the model predicts a significantly more rapid turbulent mixing in the water column than was measured, Figure 1. In both the mean and root-mean-square horizontal velocity signals the Figure 1.Comparisons between measured and modeled mean and root-mean-square velocities.

The model predictions (lines) and observations (symbols) for mean (lower panels) and root-mean-square (upper panels) velocities. Please note that the vertical velocities (left panels) are shown with a different horizontal scale than the horizontal velocities (right panels). Modeled bottom boundary layer velocity profile is significantly fuller with a small boundary layer thickness than the observations. In contrast, the vertical velocity predictions are consistent with the observations. In this case, the vertical velocity is largely induced by topographic channeling over the bedform.

Figure 2 shows a time series of observed and model predicted suspended sediment concentration over the lower 50 cm of the water column. The model predicts large suspended sediment plumes associated with individual waves as is evident in the observations. The coherent plumes following larger crests are indicative of plumes which are generated seaward of and advected past the sensor. The 2-dimensional model also shows advected plumes following the wave crests, although there exists discrepancies in the plume concentration magnitude and vertical distribution. Possible explanations for the discrepancies are model predicted near bed velocities which are higher than observed, unresolved measured bottom roughness, or a bed concentration model which is based on steady-state physics.

A closer examination of the near bed concentration is given in Figure 3. Over the same 100 seconds we compare the concentration in the lowest 1.7 cm of the water column with the integrated concentration predictions from three bed load models (Engelund and Fredsoe, 1976; Smith and McClean, 1977; Zyserman and Fredsoe, 1994). The observed near bed concentration shows frequent near bed concentration events which precede the less frequent suspended sediment plumes. The

Engelund and Fredsoe model yields the highest model-data correlation. The model yields a surprisingly good fit given the overprediction of the bed stress.

Figure 2 observed and predicted suspended sediment concentration.

A 100 second time series of the measured free stream velocity (upper panel), observed log sediment concentration (middle panel), and predicted log sediment concentration (lower panel). The colorbar indicates the magnitude of log10 concentration. Both the observations and model predictions show distinct plumes associated with larger wave crests (negative velocity).

These results are an example of how we may now directly compare field observations of velocity and concentration at a known location over complicated topography with sophisticated bottom boundary layer models. Results like these will be used to evaluate the model skill, improve the model physics and improve our interpretation of observations in the natural environment.

Figure 3 observed and predicted near bed suspended sediment concentrations.

A 100 second time series of the measured free stream velocity (upper panel) and observed near bed concentration (lower panel) and predicted near bed concentration (lower panel) for three bed load models. The model predicted concentrations are integrated over the 0.85 cm above the bed.

IMPACT/APPLICATIONS

This work is relevant to society and ONR's objectives in two distinct ways. First, existing predictive models of wave shoaling are dependent on acceptable parameterization of the of the BBL dissipation. Current models for estimating the BBL dissipation rely heavily on existing laboratory observations in idealized conditions and not in natural environments. Using both field observations and numerical modeling, this investigation will further our understanding and predictive capability of BBL dissipation in natural environments. Secondly, these results should improve our ability to predict transport and burial of movable objects on the sea floor in the coastal environment by increasing our understanding of the physics at the fluid-sediment interface.

TRANSITIONS

Model functions and observations have been shared with collaborators at the Naval Postgraduate School (Stanton and Thornton) and the University of Florida (Hanes).

RELATED PROJECTS

This project relies on the close collaboration with the Naval Postgraduate School (PI's Stanton and Thornton) and with current and future scientific exchanges with the Danish Technical University (PI's Fredsoe and Andersen). The initial scientific exchange was funded by a NICOP exchange (Co-PI's Diegaard and Bowen).

REFERENCES

Andersen, K.H. (2000). ``The Dynamics of Ripples Beneath Surface Waves and Topics in Shell Models of Turbulence." Ph.D. thesis Niels Bohr Institute, University of Copenhagen.

Engelund,F., and Fredsoe,J, (1976). "A sediment transport model for straight alluvial channels." Nordic Hydrology 7,293-306.

Foster, D. L. T. Stanton, K. Andersen, J. Freds e, and E. Thornton (2001). " Model-Data Comparisons of Velocity and Suspended Sediment in a Wave Dominated Environment". Proc. Coastal Dynamics.

Fredsoe, J., K. H. Andersen and B. M. Sumer (1999). ``Wave plus current over a ripple-covered bed." Coastal Engineering (in press).

Smith,J,D., and McLean, S.R. (1977). "Spatially averaged flow over a wavy surface." J.Geophy. Res., 82(12), 1735-1746.

Zyserman, J.A. and Fredsoe, J. (1994). "Data analysis of bed concentration of suspended sediment." J.Hydraulic Engineering,ASCE, Vol.120, No.9, pp.
1021-1042.

PUBLICATIONS

Foster, D.L., R.A. Beach, and R.A. Holman (2000). "Field Observations of the Wave Bottom Boundary Layer." Journal of Geophysical Res. Vol 105 No. C8..

Foster, D.L., R.A. Beach, and R.A. Holman (2001). "Field Observations of the Wave Bottom Boundary Layer." Journal of Geophysical Res. In Review

Foster, D. L. T. Stanton, K. Andersen, J. Freds e, and E. Thornton (2001). " Model-Data Comparisons of Velocity and Suspended Sediment in a Wave Dominated Environment". Proc. Coastal Dynamics.

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